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TECHNOLOGY

NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN

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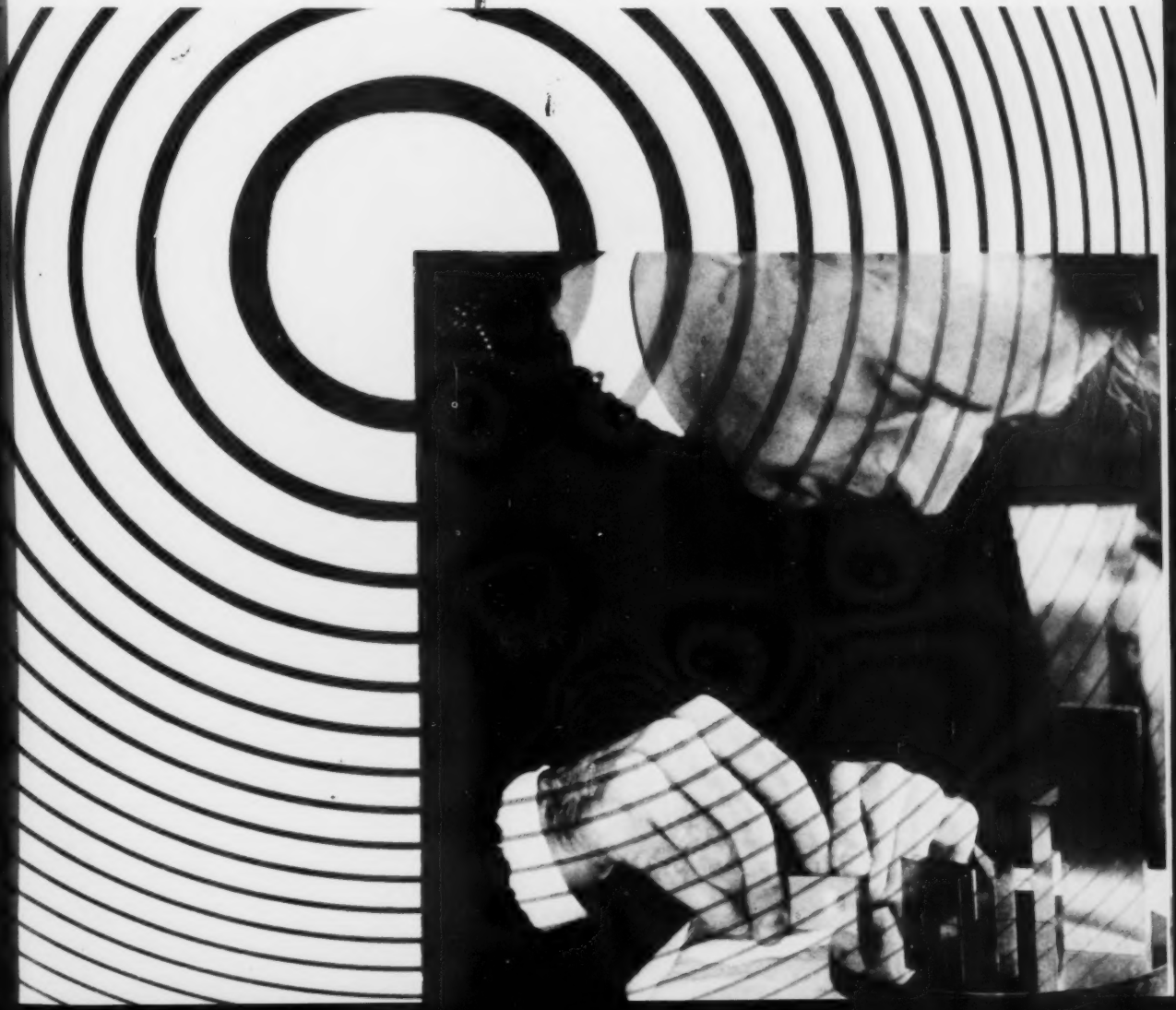
VOLUME 45 FEBRUARY 1961 NUMBER 2



U.S. DEPARTMENT OF COMMERCE — LUTHER H. HODGES, *Secretary*

NATIONAL BUREAU OF STANDARDS — A. V. ASTIN, *Director*

NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Subscription price, domestic $1.50 a year; 75 cents additional for foreign mailing; single copy, 15 cents. Use of funds for printing this publication approved by the Director of the Bureau of the Budget (June 24, 1958).

February 1961 — Issued Monthly — Vol. 45, No. 2

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COVER: Preparing to measure the lengths of gage blocks in terms of a wavelength of light. John T. Nelson wrings the blocks to a steel optical flat. When the flat is placed in an interferometer, the upper surfaces of the blocks and the flat become mirrors in the optical system. The circular pattern used as a background is an interference pattern formed with the green radiation of mercury 198. The mercury radiation is used as a working wavelength standard of length. (See "Calibration of Gage Blocks," p. 26, the first in a series of articles on the Bureau's measurement and calibration services.)

X-RAY MEASUREMENT OF

Intragranular Misorientation in Metals

AN X-RAY diffraction method has been developed at the Bureau to measure intragranular misorientation of metals—a bending or tilting of the atomic lattice within the grains—after plastic strain. The method has thus far been used to derive numerical values for this sensitive structural parameter in cartridge brass specimens. The data indicate that some of the misorientation induced by plastic deformation in tension disappears after compression. Experimental results of this work will be used in research on metal fatigue and in studying the mechanical properties of metals.[1]

Dr. C. J. Newton adjusts a newly designed instrument for obtaining X-ray measurements of the misorientation in metals after plastic strain. The X-ray beam is emitted from a copper target tube (arrow). A small rectangular metal specimen is in the mount in the center of the apparatus. (See diagram, following page.)

The grains or crystallites of which an ordinary polycrystalline metal specimen is composed may become misoriented when very small amounts of plastic strain are applied. This misorientation has been qualitatively determined in studies of metal structure; however, only a few quantitative measurements have been obtained, and these required techniques of considerable complexity. To devise a simpler technique of quantitative measurement, C. J. Newton and H. C. Vacher of the mechanical metallurgy laboratory undertook the present investigation.

A preliminary study showed that misorientation of several hundredths of a degree could be determined by means of a two-exposure photographic process. In this process, two patterns of spots obtained by X-ray diffraction from the grains in a specimen are photographed, one exposure being made while the specimen is oscillating and the film is stationary; the other, while both the film and the specimen are oscillating synchronously. The breadths of a large number of spots thus reproduced on the two films are then measured, and an average breadth for each film is calculated. From these data, a numerical value may be derived for average misorientation in the specimen.

To obtain such data, an instrument based on the design of a double-crystal spectrometer was constructed. In the first crystal position of the instrument is a stationary mount for a plane crystal monochromator; and in the second crystal position, a specimen mount that oscillates when driven by a small electric motor. A third essential part is a film holder that either remains stationary or oscillates synchronously with the specimen mount. This equipment, together with a collimator, is supported on an adjustable metal base.

One X-ray diffraction pattern is produced by directing an X-ray beam from a copper-target tube through the collimator onto a strongly diffracting single crystal of lithium fluoride in the first crystal mount. This crystal diffracts a narrow monochromatic beam through an angle onto the specimen under study in the second mount. The grains in the oscillating specimen diffract the beam through another angle onto the film, while the film holder is stationary, so that a pattern is obtained. The film is then replaced, and both specimen and film are oscillated while a second pattern is being obtained from the same specimen. Comparisons of the average breadth of the spots in the two patterns may then be made.

The specimens used in the present work were sections cut from rectangular bar specimens of brass that had previously been extended, extended and com-

Results obtained in experiments on a series of brass specimens. Average misorientation versus cumulative strain for one cycle of plastic strain of 1 percent amplitude is shown.

pressed, or extended and compressed and again extended, from 1 to 4 percent cumulative strain. Three specimens were sectioned from the reduced area in each bar: one cut parallel to the axis of loading, one perpendicular to the axis, and one cut at a 45° angle to the axis.

The various amounts of strain present, and the average misorientation found for the three sections of each bar specimen are shown in the table. Despite a considerable scatter in the data from which the averages were computed, the largest amounts of misorientation were always noted in the specimens that had been sectioned at a 45° angle to the loading axis. This result indicates that the lattice distortion of individual crystallites in a polycrystalline matrix is directly related to their orientation.

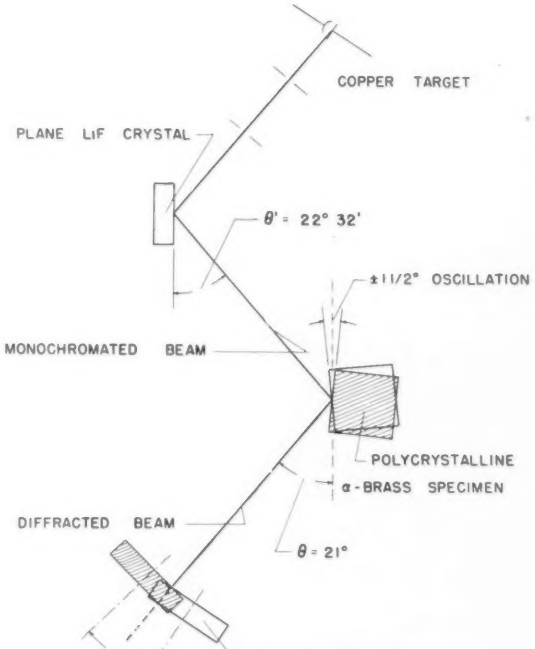
The decreased misorientation found after reversed strain in the present study may be useful in developing a theory on the reversibility of dislocations in crystallites undergoing small amounts of plastic deformation. One result of particular interest was the linear increase found in residual misorientation at zero net strain with cumulative strain. This phenomenon indicates a nonrecoverable disorder which may be attributed to the capture of some dislocations at permanent pinning points on the slip planes of a crystal.

[1] *For further technical information, see* An X-ray diffraction measurement of intragranular misorientation in alpha brass subjected to reversed plastic strain, *by C. J. Newton and H. C. Vacher, J. Research NBS* **65C**, *No. 1, 57 (1961).*

Results of intragranular misorientation measurements in brass

State of plastic deformation			Average misorientation, 1/100°			
			45° section	Cross section	Longitudinal section	Condition average
Annealed initial condition						6
Cycle position	Net strain	Cumulative strain				
Positive cycle	%	%				
¼ (E)	+1	1	33	27	23	28
½ (E–C)	0	2	13	12	10	12
¾ (E–C–C)	−1	3	67	38	28	44
1 (E–C–C–E)	0	4	25	18	11	18
Negative cycle						
¼ (C)	−1	1	32	18	28	26
½ (C–E)	0	2	18	9	15	14

E—Extended 1 percent; C—Compressed 1 percent.



Schematic arrangement of the instrument designed to obtain measurements of intragranular misorientation in metals.

Redetermination of the Half-Life of Carbon 14

A MORE accurate value for the half-life of carbon 14—important in geological and archeological dating—has recently been obtained. The new value is 5,760 years with an overall probable error of 1 percent, and is about 4 percent greater than the previously adopted value of 5,568 years.

In performing the redetermination, W. B. Mann and W. F. Marlow of the radioactivity laboratory quantitatively diluted high-specific activity carbon dioxide for counting in length-compensated internal gas counters in the Geiger and proportional regions. Mass spectrometric analyses of parts of the undiluted gas sample were made by E. E. Hughes, R. M. Reese, and V. H. Dibeler to determine the isotopic abundance of carbon 14, which was found to be approximately 44 atoms percent. Experimental details of the redetermination will be published in the near future. Intercomparative measurements of the isotopic abundance were also carried out with H. W. Wilson of the United Kingdom Atomic Energy Authority.

The redetermined value is not inconsistent with the value of 5,900 ±250 years obtained at the Bureau in 1953.[1] The value of 5,568 years that has been in use was somewhat arbitrarily chosen. Because of the wide range in measured values of the half-life of carbon 14—from 4,700 to 7,200 years—the above weighted average of three selected values [2] determined by gas counting and by mass spectrometric analysis was tentatively adopted for the purpose of radiocarbon dating of archeological samples. The present measurements have led to the conclusion that the spread in the values obtained previously may have arisen almost entirely from adsorption effects.

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[1] Disintegration rate of carbon-14, *by R. S. Caswell, J. M. Brabant, and A. Schwebel, J. Research NBS,* **53,** *27 (1954).*

[2] Radiocarbon dating, *by Willard F. Libby, p. 34 (Univ. Chicago Press, 1955).*

PLANE OF BEST AVERAGE DEFINITION FOR LENSES

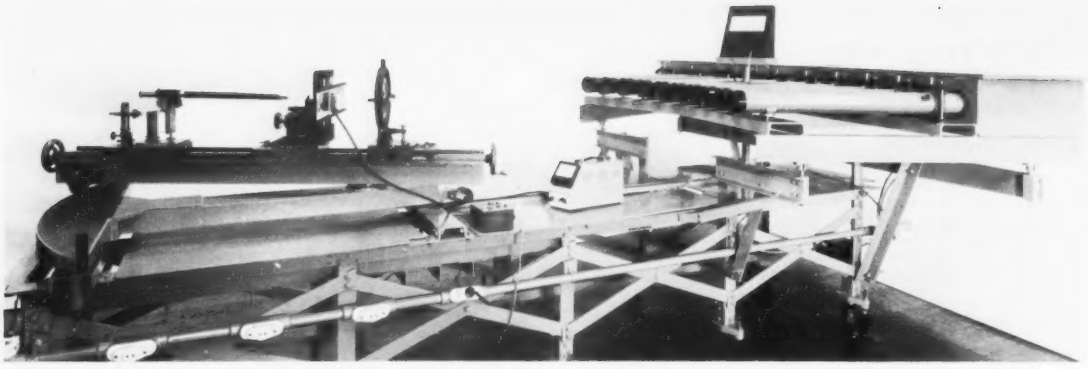
THE BUREAU has completed a comprehensive survey of the calibration methods used by other laboratories to locate the plane of best average definition in airplane camera lenses. These methods, outlined in a tentative specification proposed by the International Society for Photogrammetry, were also compared with a method presently used at the Bureau in calibrating lenses. Data from the study will facilitate interlaboratory comparisons of calibration results, and may be useful in formulating a calibration method for international adoption.[1]

The focal plane of a camera lens producing the sharpest detail over the entire picture area is known as the plane of best average definition. In calibrating a lens to locate this plane, the resolving power of the lens is found for specified areas in the several planes encompassing the region of usable imagery. In the proposed methods of the international specification, mathematical formulas are applied to these findings to derive a single value for the average resolving power at each of the different planes. The highest value thus found denotes the plane of best average definition. In the Bureau method, however, this plane is located by a simple graphical analysis of the findings. F. E. Washer and W. P. Tayman of the Bureau staff undertook the present study to compare the results obtained by the different methods.

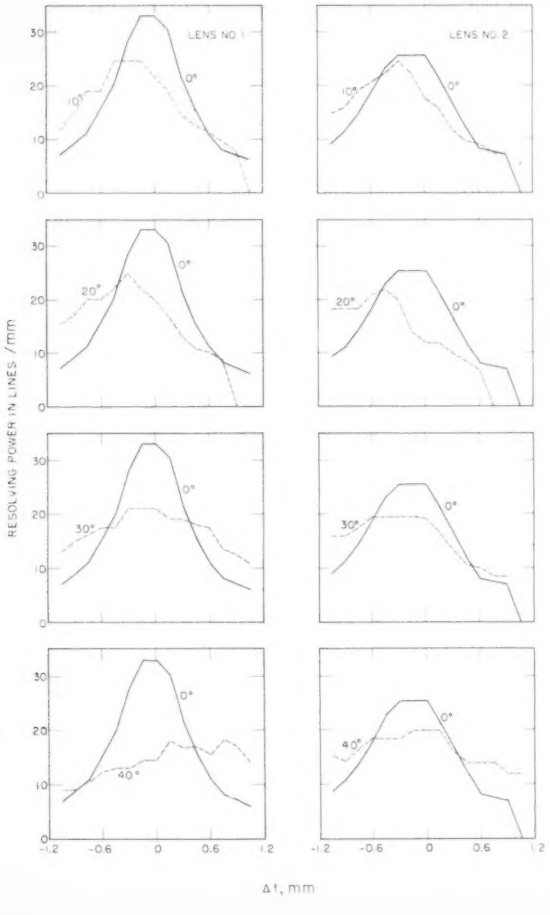
A precision lens-testing instrument [2] was used to obtain data for the study. It consists of a viewing microscope, a photographic plate holder, and a lens holder mounted in sequence along a movable carriage at one end of an optical bench, and a fan of 10 collimators facing the carriage assembly at the other end of the bench. Each collimator has a resolving power test chart as a reticle.

These charts contain a series of patterns consisting of two sets of three parallel lines—one set horizontal, the other vertical—placed at right angles to each other. The patterns decrease successively in size by a ratio equal to the fourth root of two. The size of the smallest pattern, as observed under magnification, permits a theoretical determination of radial resolving power (measured by means of the horizontal lines) and tangential resolving power (measured by means of the vertical lines) of 264 lines/mm.

In the present study, only five collimators, fixed at 10° angular separations from 0° to 40° were used. To obtain a test negative, a lens was placed in the lens holder at the intersection point of the collimator axes; the carriage with its assembly was aimed at the first (or 0°) collimator, coinciding with the lens axis; and the photographic plate holder was moved along the carriage until the plane of best visual focus was found. From that position, the plate holder was moved forward (toward the lens) to a plane 1.05 mm *inside* the position of best visual focus and an exposure was made. Thus one horizontal row of the charts in the five collimators was registered on the negative.



Above: Equipment used to locate the plane of best average definition in airplane camera lenses. The lens under test, a photographic plate, and a viewing microscope are mounted on a movable carriage at one end of an optical bench. At the other end of the bench a fan of collimators faces the carriage assembly. Below: The resolving power of two lenses through the region of usable imagery is plotted for angles ranging from 0 to 40°.



To register succeeding rows for the planes in the region of usable imagery, the plate holder was moved backward (away from the lens) in steps 0.15 mm apart, and the process was repeated at each step until a total of 15 exposures had been made. The final row was registered at a position 1.05 mm *outside* best visual focus. After each exposure, the photographic plate was moved downward to avoid superimposition of successive rows. These adjustments caused the central row of charts to register at the plane of best visual focus.

Negatives for four lenses were obtained in this manner. To derive numerical values for resolving power, the completed negatives were examined under a magnification of from 30 to 50. Criteria used for deciding that a particular pattern was the finest pattern resolved in a given chart were (1) all coarser—

TABLE 1. *Resolving power in lines per millimeter for a series of focal planes in a lens encompassing the region of usable imagery*

Focal planes	Resolving power obtained for tangential (T) and radial (R) lines for angles at:									
	0°		10°		20°		30°		40°	
	T	R	T	R	T	R	T	R	T	R
min										
−1.05	7	7	13	10	17	14	12	14	6	14
−0.90	10	8	19	11	17	17	12	19	6	14
−.75	12	10	22	16	20	20	14	19	8	14
−.60	17	14	22	16	20	20	16	19	8	19
−.45	20	20	22	27	22	22	16	19	9	19
−.30	28	28	22	27	22	28	20	22	9	19
−.15	33	33	22	27	22	22	20	22	11	19
0	33	33	22	22	20	20	20	22	11	19
0.15	28	33	22	16	20	14	23	16	13	23
.30	23	20	16	13	17	10	23	16	15	19
.45	14	17	16	10	14	8	23	14	15	19
.60	10	12	16	8	14	7	28	11	15	16
.75	8	8	13	7	12	6	23	8	21	16
.90	7	7	11	6	10	0	20	8	18	16
1.05	6	6	9	0	10	0	20	6	18	11

TABLE 2. *Location of the plane of best average definition selected by each of the three single-valued indices and by the graphical method for four lenses*

The boldface value of each index is its maximum value; the boldface focal plane value is that selected by the graphical method. Values for the selected planes (and in the case of lens No. 3, two neighboring planes) are given for ready comparison.

Lens no.	Focal planes	Graphical analysis data, Collimator angles					AWAR	ADWAR	$\sqrt{\overline{R_B T_B}}$
		0°	10°	20°	30°	40°			
1	−0.30	28.0	24.4	24.8	21.0	13.1	**20.2**	**22.3**	22.8
	−.15	**33.0**	24.4	22.0	21.0	14.5	19.9	21.9	**23.7**
2	−.45	23.0	22.0	22.0	19.5	18.5	**20.0**	20.9	21.1
	−.30	25.4	24.4	20.0	19.5	18.5	19.8	**21.0**	**21.7**
3	−.30	28.0	22.0	21.0	17.4	16.9	18.6	19.7	21.4
	−.15	28.0	22.0	21.0	19.5	18.6	**19.9**	**20.6**	**22.1**
	.00	25.4	22.0	20.0	18.8	18.5	19.4	20.0	21.1
4	−.15	25.4	27.0	21.8	18.8	14.4	19.2	**21.0**	**22.0**
	.00	28.0	22.0	19.3	21.0	15.5	**19.3**	20.1	21.5

that is, larger—patterns were clearly resolved and (2) the number of lines of a given pattern in the negative were the same as those of the corresponding pattern in the test chart. The examinations showed the greatest number of lines that could be separately distinguished, both radially and tangentially, in all of the charts in the negatives. A representative set of observations is given in table 1.

From the data thus compiled, single values were derived for the plane of best average definition in the lenses by the following methods: Application of a formula by which the area-weighted average resolution (AWAR) could be computed; application of a formula by which the area-weighted and depth-of-focus weighted average resolution (ADWAR) could be computed; computation of the root-mean-square mean resolution ($\sqrt{\overline{R_B T_B}}$). The data were also used to plot the variations in resolving power across the various planes in the region of usable imagery for each of the five angles, according to the Bureau method. The graphs were then analyzed to locate the plane of best average definition in each of the four lenses.

Table 2 gives a comparison of the results derived by the four methods. Although the same plane of best average definition was selected by all the methods for only one lens, the planes selected for the three other lenses by each method were within 0.15 mm of each other. However, the average values for resolving power showed considerable variation.

[1] *For further technical details, see* Location of the plane of best average definition for airplane camera lenses, *by Francis E. Washer and William P. Tayman, Photogrammetric Engineering,* **26,** *475 (1960).*

[2] Precision camera for testing lenses, *by I. C. Gardner and F. A. Case, J. Research NBS* **18,** *449 (1937) RP984.*

announcing . . .

1960 RESEARCH HIGHLIGHTS

. . . of the National Bureau of Standards

. . . an illustrated digest of the Bureau's measurement and research activities during fiscal year 1960. *Research Highlights* describes specific accomplishments in the Bureau's vigorous and imaginative research program in the physical sciences . . .

Including: New value for the faraday; new atomic weight of silver; and a continuing program to obtain more accurate values for various other basic constants of nature, such as the acceleration of gravity.

Also: Development of high-stability gage blocks and ultraprecise techniques for their measurement; the certification, for the first time, of commercial blocks to an accuracy of one part in five million.

Other Topics: Electronic calibrations, free radicals research, high-temperature thermocouples, pressure measurements, radiation measurement and protection, plasma physics and laboratory astrophysics, atomic frequency and time interval standards.

1960 RESEARCH HIGHLIGHTS OF THE NATIONAL BUREAU OF STANDARDS, NBS Miscellaneous Publication 237, 189 pages, $0.65. (Order from Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.)

STANDARD MATERIALS

The Bureau is now distributing 60,000 samples of standard materials a year for use in controlling chemical processes and in maintaining the accuracy of apparatus and equipment. Over 600 different standard materials are available from the Bureau—principally chemicals, ceramics, metals, ores, and radioactive nuclides. All are certified either for chemical composition, or with respect to a specific physical or chemical property such as melting point, viscosity, or index of refraction.

Within the past 5 years, requests from American science and industry have resulted in the issuance of about 70 new standard materials. Meanwhile, 150 new standard materials are being prepared for issuance through programs of careful analysis and precise measurement.

THIS standard materials column is being initiated as a regular Technical News Bulletin feature in response to numerous requests from individuals and organizations. It will serve as a medium for distributing news of new standard materials, changes in certificates, samples out of stock, references to NBS articles on standard materials, reviews of plans for standards, and revisions in the standard materials catalog, NBS Circular 552.

Circular 552, *Standard Materials Issued by the National Bureau of Standards,* is available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., for $.35.

Radionuclides: Two new gamma-ray standard samples of radionuclides, scandium 46 and manganese 54, are now available from the Bureau. The scandium nuclide has a half-life of 8.3 days, while the manganese nuclide has a half-life of 308 days. Although each of these nuclides are available for $32.00, they are issued in different forms. The scandium sample is prepared in (5. ml) solution form, and the manganese is available as a point-source deposited on mylar film.

Because the scandium sample can be issued only under the special licensing provisions of the Atomic Energy Act of 1954, it is required that a copy of the purchaser's current AEC By-Product Material License be on file at the Bureau. However, the manganese sample can be ordered under the general licensing provisions.

All orders for radioactivity standard materials should be addressed to: Elizabeth M. Zandonini, Radioactivity Standard Samples, Radioactivity Section, National Bureau of Standards, Washington 25, D.C.

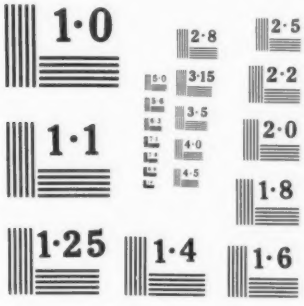
Microcopy Resolution Test Chart: One of the more unusual standard samples issued by the Bureau is the Microcopy Resolution Test Chart prepared by the photographic research laboratory. About 12,000 charts, which are used to test the performance of lenses, are sold each year to the microfilm industry.

The instructions for the use of the chart have recently been revised. The new version is given below:

In general, the reduction in dimensions of documents by the use of a microcopying camera is limited by the resolving power of the lens, the resolving power of the photographic material, inaccuracy of focusing, vibration, and systematic relative motion of the optical image with respect to the photographic material. In order to evaluate the performance of microcopying systems, the resolution test chart was prepared. This chart consists of a series of black parallel-line patterns on a white background, the lines and spaces being of equal width. Each pattern contains two groups of 5 lines, at right angles to each other. The patterns range in spacial frequency from 1 to 10 lines per millimeter. (It is conventional in photography to consider a line and the adjoining space together as "one line.") Three of these charts are placed on the copy board of the camera so that one chart is in the center of the field, one at the center of the long side, and another at the corner. The last two charts are oriented so that one group of lines of the patterns is radial with respect

to the center of the field and the other group of lines is tangential.

The array of charts is then photographed in the same manner as documents. To test the focus of the lens a series of photographs is made with small changes in focus, keeping a record of focusing scale settings for future reference. After the films have been developed, the negatives are examined with a microscope. The magnification should be from ⅓ to 1 times the number of lines per millimeter to be observed. For example, to view 100 lines per millimeter, the microscope magnification should be between 30 and 100. The number of lines per millimeter, in the smallest pattern in which the lines can be counted with certainty, multiplied by the reduction ratio, gives the resolving power of the system. For example, if the smallest pattern resolved has 5.0 lines per millimeter and the reduction ratio is 19, the resolving power is 95 lines per millimeter.



Microcopy resolution test chart.

In the center of the field the resolution should be independent of the orientation of the patterns. Away from the center of the field, it is usually found that the resolution for radial and tangential patterns is not the same and, furthermore, changes with the distance. This effect is caused by aberrations of the lens. If, in the center of the field, the resolution of lines in one direction is less than for those in another direction, it is likely that the camera was vibrating during exposure or that there was relative motion of the image with respect to the film. In order of check the camera for vibration, make several exposures with the chart in the center of the field in one orientation, then turn it through an angle of 45° and make several more exposures. If the lines in both directions at both orientations are equally resolved, the camera is free from vibration.

In cameras of the type in which the document being copied and the film move during exposure, there is the possibility that the motions may be improperly matched so that the optical image moves with respect to the film. This can be checked by photographing resolution charts at the center of the field. If the camera is properly adjusted, the lines parallel to the direction of motion and perpendicular to it will be equally resolved. Otherwise the lines parallel to the direction of motion will show a higher resolution than those perpendicular.

The lowest resolution in any part of the picture area, the size and style of type, contrast, color of paper and ink, and the reduction ratio are factors determining the quality of reproduction on microcopying film. Three grades of reproduction, sufficient for the needs of practical microcopying, have been defined. They are:

1. Excellent copy—details of type are clearly defined.
2. Legible copy—readable without difficulty although serifs and fine details of type are not clearly defined.
3. Decipherable copy—readable with difficulty, letters, e, c, and o are partly closed.

A correlation of these factors for commonly used styles of types has been established for these three grades of reproduction as follows:

1. For excellent copy, the height of the lower case letter e, as recorded on the film, should not be less than the distance across eight lines of the smallest resolution pattern resolved by the system.
2. For legible copy, the height of the e should be not less than the distance across five lines of the smallest pattern resolved.
3. For decipherable copy, the height of the e should be not less than distance across three lines of the smallest pattern resolved.

For example, if it is desired to copy a newspaper, on which the height of the smallest e is 1.5 mm, at a reduction ratio of 19×, the minimum resolution required for the three grades of reproduction are:

1. For excellent copy, 101 lines per millimeter.
2. For legible copy, 63 lines per millimeter.
3. For decipherable copy, 38 lines per millimeter.

It is recommended that several photographs of the resolution charts be made on every roll of microcopy film used, preferably at both ends of the roll. This practice provides a convenient means of checking the operation and performance of the microcopying equipment, and provides a record which can be referred to later.

Calibration of Gage Blocks

first of a series on NBS measurement services

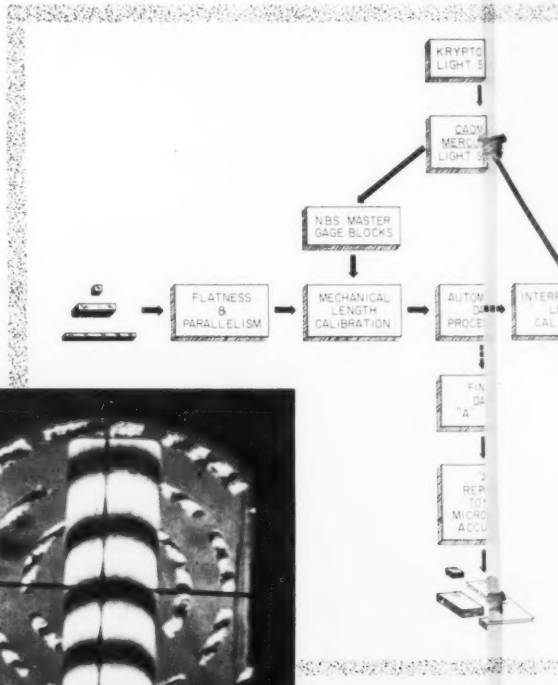
THE FOLLOWING article is intended as one of a series on Bureau activities in direct support of its mission to disseminate a uniform system of measurements adequate to the needs of science and industry. Widespread interest in these NBS measurement services has recently been stimulated, in part by the increase in the sheer volume of calibration needs and in part by the continuing advances in the level of precision required for rockets, artificial satellites, and other space-age systems, as well as for other advanced sectors of technology. These changes have in turn been reflected in an impressive increase in the number of standards laboratories operated by private industry and the various defense agencies; and in determined efforts on the part of these groups to see that measurements in all critical areas are clearly "traceable" to the national standards.

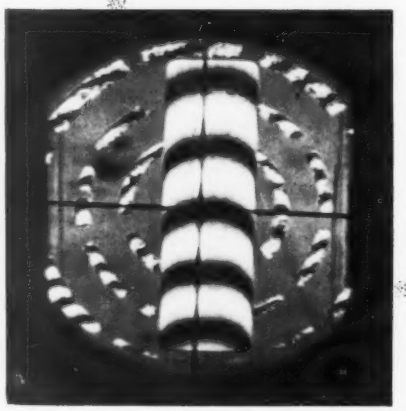
It is NBS policy to concentrate its calibration efforts on the master standards of high-level standards laboratories and on other equipment requiring the highest attainable accuracy. In all other cases, needed calibrations are referred to standards laboratories at a level below the Bureau in the calibration hierarchy. Such restrictions are necessary in order not to impair other essential parts of the NBS mission. If the Bureau is to meet not only today's needs for high precision, but also the anticipated severe requirements of a few years hence, then it must maintain a strong program of research on new standards, on standards of improved accuracy and wider range of applicability, on more precise and efficient measuring techniques and instrumentation, and on the closely related problems concerned with the determination of physical and chemical constants and the properties of materials.

In response to the mounting interest in calibration matters, the Bureau has in the past few years cooperated with industry and the armed forces in a number of projects that supplement existing liaison arrangements. It has stepped up its efforts to assist other standards laboratories in setting up calibration services. It advised the Aerospace Industries Association on a proposed questionnaire to obtain information about standards and measurement problems among AIA member companies. It participated in cooperative studies with the Air Force in other surveys of the same nature, with particular attention to the needs of defense projects. As a result of the AIA questionnaire replies, a series of AIA-sponsored Measurements Research Conferences has been initiated between representatives of industry and staff members of NBS. Two new NBS advisory committees have also been established: Calibration and Measurement Services, and Engineering and Related Standards.[1]

BY CALIBRATING from 5,000 to 6,000 gage blocks submitted to it each year, the Bureau's gage-block laboratory is currently providing industry with one of its most effective means of monitoring the increasingly close dimensional tolerances that are required for interchangeability of parts and reliable performance in complex modern devices. Calibrations with uncertainties as low as one part in a million (see table), are routinely available,[2] permitting industry in turn to use the gage blocks for calibrating other equipment with only slightly less accuracy. However, gage blocks of the highest attainable accuracy are also being applied directly in "custom" production work on critical projects.

In principle, it should be possible to provide calibrations of substantially higher accuracy as a result of (1) the recent adoption of a wavelength standard of length,[3] and (2) improvements in use of auxiliary



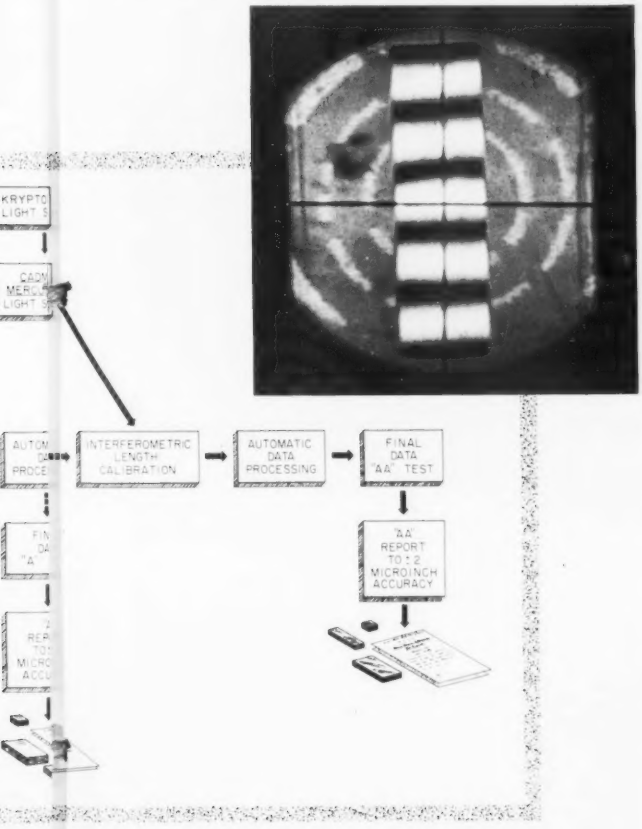


Block diagram of procedur "A" report, in w gage blo for "inspection q" block oratory quality" b. To d ferometric patter obtain of the block (upright) i indicated when th es are c

equipment, such as interferometers,[4] needed in comparing wavelengths of light with the lengths of meter bars, gage blocks, or other solid objects. The main obstacle to the provision of such higher accuracies on a routine basis has been the dimensional instability of even the best alloys commercially available for manufacturing gage blocks. In special cases it has been possible to certify gage blocks to an accuracy of better than 1 part in 5 million. Research is now under way at the Bureau [5] to find alloys which, it is hoped, will permit regular calibrations to 1 part in 10 million.

Gage Block Applications

In its simplest form, a gage block is a rectangular block of steel with square or oblong cross section and with two of its opposite faces ground and lapped flat and parallel to one another.[6] The length of the block is defined as the perpendicular distance between the latter two faces; or, for highest precision, between one of the faces and a specified point on the other.



am of procedure followed in calibrating precision gage blocks. The in which gage blocks are certified to an accuracy of ±4 μin., is issued ion q" blocks, and the "AA" report (±2 μin.) is issued for "lab- lity" is. To determine the degree of flatness in gage blocks, inter- patterns obtained. Straight broad lines appearing on the surface k (upright) indicate a high degree of flatness. Non-flatness is hen the es are curved (left).

The surfaces of a block defining its length are called gaging surfaces. These extremely flat and highly finished surfaces make possible two very useful characteristics of gage blocks: (1) They can be measured directly in terms of wavelengths of light by interferometric methods in which light beams are reflected from the gaging surfaces; (2) by carefully sliding a gaging surface of one block over a gaging surface of another, the two blocks can be "wrung" together so that they offer considerable resistance to separation, and it has been shown that the thickness of the film between the blocks is normally well below 1 μin. (If it is necessary to combine large numbers of blocks, they may be supported in a gage holder. Some are made with a cylindrical hole in each perpendicular to the gaging surfaces, so that the blocks can be held together by a bolt passing through the hole.)

A typical set consists of 81 gage blocks, with sizes ranging from 0.05 to 4 in. Of the 81, there are 10 blocks with lengths from 0.1000 to 0.1009 in., in steps of 0.0001 in.; 50 blocks from 0.101 to 0.150 in., in steps of 0.001 in.; 17 blocks from 0.20 to 1.00 in., in steps of 0.05 in.; and single blocks with lengths of 0.05, 2, 3, and 4 in. With these 81 blocks, over 100,000 combinations of measurement are possible in steps of one ten-thousandth of an inch. By the additional use of 0.100025-, 0.100050-, and 0.100075-in. blocks, combinations may be made in steps of as little as 25 millionths of an inch.

Many industrial and scientific laboratories maintain one or more sets of master gage blocks which are used only to calibrate working sets; and the latter are used for direct measurements or for calibrating various kinds of measuring instruments. Among many other applications, the blocks serve to test the accuracy of micrometer calipers, and of ring, plug, and snap gages; to check the lead of screw-thread gages; to calibrate strain gages, and mechanical or electronic indicating gages and comparators; and they are used with sine bars for precision angle measurements. At the Bureau they are often employed in the measurement of derived quantities. In the calibration of precision barometers, for example, gage blocks are used in determining the height of the mercury column. A more unusual application was the construction of a "computable" electrical capacitor (i.e., one whose capacitance can be calculated with high accuracy from its geometrical dimensions) out of gage blocks whose lengths were measured in the gage-block laboratory.[7]

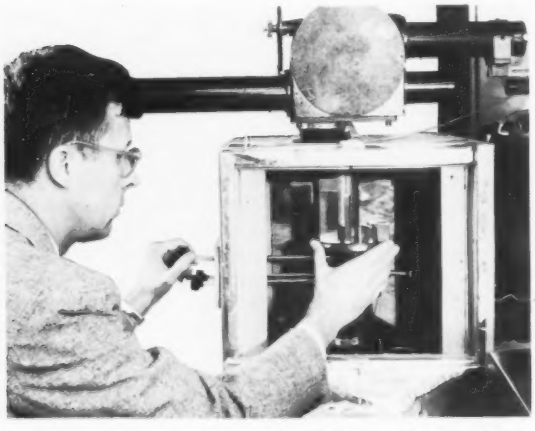
Precision gage blocks are classified into Grade AA or laboratory quality blocks and Grade A or inspection quality. Laboratory quality blocks are manufactured to within a few microinches of their nominal length, that is, the length indicated on the block. As mentioned above, gage blocks exhibit a dimensional instability with the passage of time, an effect that is in addition to the changes due to wear. In the case of master blocks that are seldom and very carefully handled, the change due to wear is quite small; while the change caused by instability may, in some cases,

Above: With a slight pressure, gage blocks may be wrung together in this manner to make highly accurate measurements of lengths which cannot be represented with a single block.

amount to several microinches per year. It is therefore considered necessary to recalibrate master blocks at intervals of from one to several years, depending on the type of usage and level of accuracy.

Calibration Procedure

The first step in the Bureau's calibration procedure is to test the gaging surfaces for flatness and parallelism. Blocks with excessive deviations in either of these respects are as a rule not calibrated; or, if they are, the accuracy of the measurements is not certified.



John S. Beers, in charge of the NBS gage-block calibration laboratory, inserts an optical flat, to which gage blocks have been wrung, into one of the interferometers used to measure the lengths of the blocks by means of light waves.

In maximum precision applications, it may be necessary to take into account even fairly small deviations, since lack of flatness or parallelism means that the length of the block will vary from point to point on the gaging surfaces.

The lengths of all blocks submitted for calibration are then determined by comparison with NBS master blocks of the same nominal size. These master blocks are calibrated against the laboratory's reference standards, light waves produced by cadmium and mercury 198. The lengths of these light waves are known very accurately in terms of the new international standard of length, the wavelength of the orange-red spectral line emitted from atoms of krypton 86. Electromechanical comparators of the dual transducer type show the difference in length between master block and test block. Each test block is compared at least twice with the master blocks. Tongs are used to handle the blocks so that variations from the 68 °F temperature maintained in the laboratory will be held to a minimum.

Length measurements obtained with one of the electromechanical comparators used in calibrating gage blocks are recorded by Mrs. Grace Chaconas.

Data from the electromechanical comparators are recorded on punched cards for processing in a high-speed electronic computer which calculates the deviation of each block from its nominal length. In arriving at an average value for the block, the computer examines both comparisons for excessive spread or variation between their values. When too much spread is noted, the block must be recalibrated.

If the set is being given an "A" calibration, the test is now complete and the final report is assembled. This report consists of a table showing the nominal size, identification, deviation from nominal length of each block, and any excessive deviations in flatness and parallelism. A text explaining the calibration is attached to the report. The accuracies obtained in calibrating "A" blocks are listed in the table.

Peter Newfeld places gage blocks in an interferometer used in calibrating "Grade AA" blocks.

Calibration services of the NBS gage-block laboratory [8]

Nominal value	Accuracy of calibration*	Remarks
in.	*μin.*	
0.010 to 0.090	±3	Blocks in this size range are usually warped and do not warrant calibration to a higher accuracy. If errors in flatness are not excessive, it may be possible to calibrate blocks 0.040 in. and thicker to an accuracy of ±2 μin.
0.100 to 2.000	±2 or ±4	Two types of calibrations are available for gage blocks in these size ranges: Type AA, intended primarily for Grade AA (laboratory) quality blocks, is indicated by the first listed accuracy at left; Type A, intended primarily for Grade A (inspection) quality blocks is indicated by the second listed accuracy.
2 to 3	±3 or ±5	
3 to 4	±4 or ±6	
5 to 20	±1 per inch of length	Accuracy contingent on quality of gaging surfaces.

*The accuracies listed are those routinely provided. Higher accuracies may be provided upon special arrangement if the quality of the gage block permits.

When accuracies of a higher degree are required ("AA" calibration), interferometric measurements with light waves are made. Because the blocks are wrung to steel optical flats for measurements, the gaging surfaces must be completely free from burrs and substantially in "new block" condition. After wringing, sufficient time is allowed for temperature equalization. The flats are then placed in the interferometer where the upper surfaces of the blocks and the flat become mirrors in the optical system.

Two interferometers, in which cadmium and the mercury isotope 198 are the light sources, are used to make two separate sets of measurements. The light from these sources consists of a number of monochromatic radiations (spectral lines), one of which is used from each source. Two determinations are made, using each source in turn; the blocks are then wrung to another optical flat, and this operation is repeated. Each of the spectral lines produces a pattern of optical interference fringes which serves, in effect, as a finely divided scale. One division on these scales corresponds to half a wavelength of the light used (approximately 0.00001 in.), and it can be subdivided into tenths (approximately 0.000001 in.) without difficulty. During the measurements, precise determinations are made of air temperature, barometric pressure, and humidity, since these factors affect the wavelength of light by changing the index of refraction of air. Temperature of the blocks is also measured and corrections are applied so that the final reported lengths are at the standard temperature of 68 °F.

The additional data obtained from the interferometric measurements, such as observed interference fringe fractions, phase shift corrections, coefficient of expansion, temperature, barometric pressure, and humidity, are then fed into the computer which uses them to calculate the length of each block at 68 °F. It is interesting to note that from computations such as these, the ac-

Donald R. Johnson measures the parallelism of a set of gage blocks with an interferometer developed at the Bureau.

curacy of the Bureau's master gage blocks is indirectly verified. This verification is accomplished by comparing the results of the mechanical comparisons with those of the interferometric comparisons.

The final report for the "AA" calibration is essentially the same as that computed for an "A" calibration except that more stringent requirements for flatness and parallelism are observed, and higher accuracies, as shown in the table, are obtained.

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[1] *These activities have been described in the following NBS Technical News Bulletin articles:* Assistance to other standards laboratories, **43**, 21 *(Feb. 1959)*; Standards and calibration activities in rapid growth, **43**, *221, (Dec. 1959)*; Measurement research conferences, **45**, *1 (Jan. 1961)*; Two technical advisory committees established, **45**, *16 (Jan. 1961)*. *See other articles in the December 1959 issue for accounts of some NBS research projects on improved standards and measurement techniques.*

[2] *For information on NBS calibration services, see* NBS Test Fee Schedule, *available upon request from Publications Section, National Bureau of Standards, Washington 25, D.C.*

[3] Wavelength of Kr^{86} light becomes new international standard of length, *NBS Tech. News Bul.* **44**, *199 (1960)*.

[4] Interferometer for measuring gage-block parallelism, *NBS Tech. News Bul.* **42**, *30 (1958)*; Gage block length measurements with the parallel-testing interferometer, *NBS Tech. News Bul.* **44**, *165 (1960)*.

[5] Extremely stable gage blocks for precision measurements, *NBS Tech. News Bul.* **44**, *82 (1960)*.

[6] *For a more detailed elementary introduction to gage blocks, see, for example,* Precision measurement in the metal working industry, *prepared by the Department of Education of the IBM Corp. (Syracuse Univ. Press, 1952)*.

[7] New apparatus at NBS for absolute capacitance measurement, *by M. C. McGregor, J. F. Hersh, R. D. Cutkosky, F. K. Harris, and F. R. Kotter, IRE Trans. Instr.* **I–7**, *Nos. 3 and 4 (double issue), p. 253 (Dec. 1958)*; New capacitance standards, *NBS Tech. News Bul.* **42**, *229 (1958)*.

[8] *Other types of end standards, ranging in length from 4 to 72 in., are calibrated by the NBS engineering metrology laboratory to an accuracy of ±1 to ±5 μin. per inch of length, the accuracy obtained depending on the quality of the gaging surfaces.*

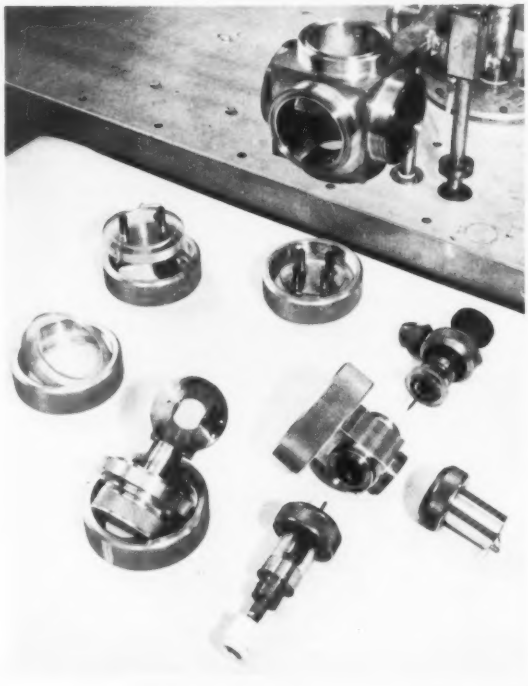
Apparatus for Vacuum Evaporations

A VERSATILE vacuum chamber has been constructed at the Bureau for preparing the replicate specimens used in electron microscope studies. Designed by H. C. Vacher, H. C. Burnett, and R. H. Duff, the chamber has several access ports to which attachments may be fitted for making different types of specimens; a small volume that may be evacuated to a pressure of less than 10^{-4} mm of mercury in about 7 min; and an externally adjustable specimen stage that permits the required angles to be obtained for a series of vacuum evaporations without reevacuating the chamber.

In preparing specimens for examination by an electron microscope, two different methods are generally employed. In one of these methods, tungsten trioxide or metals such as palladium or chromium are "shadow cast" at an inclined angle on a plastic replica previously prepared of the surface under study. Carbon or silicon monoxide is then vacuum-deposited at normal incidence, to impart to the specimen a high degree of stability in the electron beam. After removal from the chamber, the plastic replica is chemically dissolved to complete the specimen preparation.

In the other method, a dehydrated wetting agent is vaporized directly on the surface under study. Either a plain carbon or a pre-shadowed carbon specimen is then prepared by vacuum evaporation in the manner outlined above. The vaporized wetting agent facilitates the stripping of the specimen from the surface substrate.

The vacuum chamber developed at the Bureau to accomplish these evaporations is made of brass in the shape of a cube 4½ in. square. Ports in five sides of the chamber accommodate interchangeable attachments. A port machined in the sixth side is adaptable



Vacuum chamber and components for equipment used in preparing electron microscope specimens. Directly under the chamber body is an apparatus for vaporizing a dehydrated wetting agent, and then in clockwise order, a disassembled unit for carbon deposition; the specimen stage attachment; a port window; and a metal evaporating unit.

to various types of evacuating units. Port windows are made of lucite, and O-rings are used to make tight closures. Epoxy adhesive is employed to seal electrical connectors into the various attachments.

The port opposite the evacuating system is used to admit a stage component on which several specimens may be mounted. After the chamber has been evacuated, the stage may be manually rotated to any desired angle with respect to the remaining four ports. One of these serves as an observation window, and two others accommodate attachments for shadow casting metals and for depositing carbon. The last port is fitted with a wetting agent fixture when a specimen is being prepared directly from the surface under study. When a plastic replica is used in preparing the specimen, this port may be fitted with an additional window for observation purposes.

Vacuum chamber developed for preparation of electron microscope specimens. Pedro Sarmiento inserts a rotatable stage into the chamber. The unit for depositing carbon is fitted to the port on the right, and the metal evaporating unit is attached to the port on top.

Cross Linkage of Natural Rubber

THE EFFECTS of cross linkage upon certain of the physical properties of natural rubber [1] have been investigated at the Bureau. L. Mandelkern and D. E. Roberts of the polymer structure section have found that many properties of cross linked rubber depend not only on the number of cross linkages present but also on the disposition of the chains prior to cross linking. This research is part of a continuing program being conducted at the Bureau to investigate the fundamental physical properties of macromolecules.

Natural rubber represents one of the simpler types of macromolecular systems, each chain being comprised of the same repeating unit. A high degree of orientation can be induced in this polymer by rapid stretching at elevated temperature and allowing it to crystallize by cooling. Three-dimensional networks are formed from either random or oriented chains through chemical reaction or by the action of high-energy ionizing radiation. Such a network is insoluble in the usual rubber solvents and is characterized by reversible long-range elasticity in the liquid state.

In order to study the effects of cross linkage on isotropic length, thin strips of the polymer were formed by casting natural rubber latex on glass plates, followed by air-drying for 15 days. A high degree of chain orientation, as indicated by X-ray diffraction examination, was produced in these strips by rapid stretching ("racking") at 80 °C, followed by quick cooling to 20 °C while in the elongated state. This racking process resulted in strips that were 11 times original length after the elongating forces had been removed. When heated to 42 °C, rapid retraction of racked specimens occurred. Cross linkage was produced in these oriented chains by the action of gamma rays from either a 50- or 200-curie cobalt 60 source. The racked samples were immersed in boiling water after irradiation to insure retraction, and were measured after drying to determine the isotropic length, which is defined as the length of the amorphous (liquid state) network in the absence of any external force. X-ray and density studies indicate that the racking process does not produce perfect orientation nor unduly high levels of crystallinity.

It is well known that no change in isotropic length occurs when random chains are cross linked. However, it was found that the isotropic length of oriented chains increases as cross linkages are introduced. It was also noted, from sol-gel determinations and swelling studies, that a given amount of radiation produced twice as much cross linkage in the oriented chains as it did in random chains.

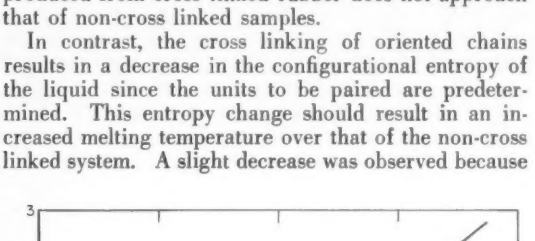
The initial cross linkages have only a slight effect on the isotropic length of oriented specimens. However, after about 1 percent of the chain units have been cross linked, the isotropic length increases in direct proportion to the square root of the fractions of units cross linked, as predicted by theoretical studies.[2] This process produces a deformed amorphous network without the application of an external force. Subsequent studies on other polymers have shown that an oriented crystalline state can be obtained on cooling such networks, which leads to a coupling of contractile processes with the crystal-liquid transformation in polymers.

The change in isotropic melting temperature produced by cross linkage was determined for both random and oriented chains. Cross linkages were introduced in random and oriented chains by means of γ-radiation, and in random chains by reaction with sulfur or di-tert butyl peroxide. Crystallinity was developed in the amorphous networks by maintaining the specimens at -30 °C for 75 days. The isotropic melting tempera-

ture, at which crystallinity completely disappears in the absence of any external force, was then determined by dilatometric techniques, employing very slow heating rates. As the melting temperature was approached the temperature increase was limited to 1° in 10 days.

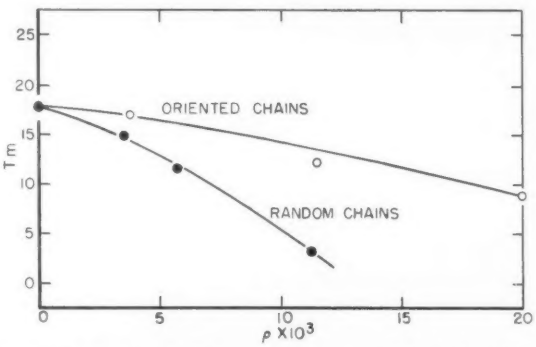
When random chains are cross linked the chain configurational entropy remains unaltered. However, cross linking does produce a slight change in the composition of the melt so that a small depression of the melting temperature would be expected. The observed depression was found to be much greater, which can be attributed to the fact that the perfection of crystallinity produced from cross linked rubber does not approach that of non-cross linked samples.

In contrast, the cross linking of oriented chains results in a decrease in the configurational entropy of the liquid since the units to be paired are predetermined. This entropy change should result in an increased melting temperature over that of the non-cross linked system. A slight decrease was observed because of imperfections, but the melting temperatures are substantially greater than those of networks formed from random chains. For example, at 1 percent cross linking the melting point of networks formed from random chains was lowered 26°, whereas the change for networks formed from oriented chains was only a few degrees. In essence, a partially ordered liquid is formed by cross linking oriented chains.



[1] *D. E. Roberts, L. Mandelkern,* The melting temperature of natural rubber networks, *J. Am. Chem. Soc.* **82,** *109 (1960). See also:* Some properties of polymer networks formed from oriented chains of natural rubber, *D. E. Roberts, L. Mandelkern, J. Am. Chem. Soc.* **80,** *1289 (1958).*

[2] *P. J. Flory,* Theory of elastic mechanisms in fibrous proteins, *J. Am. Chem. Soc.* **78,** *5222 (1956).*



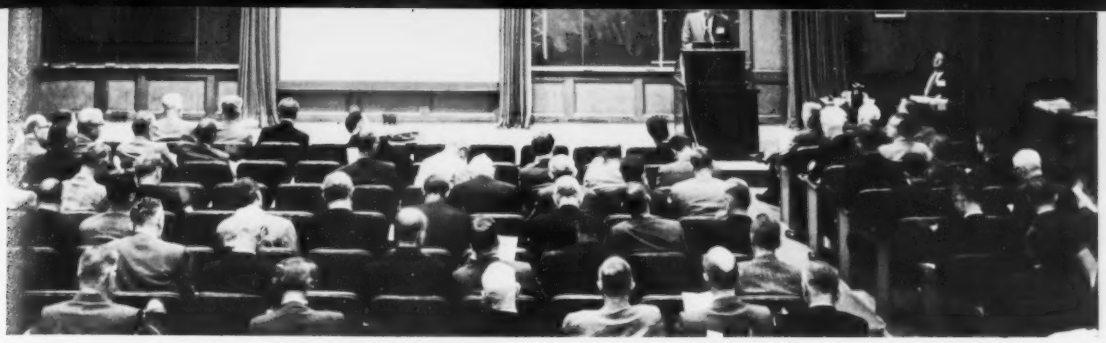
Left: when plotted against the square root of the fraction cross linked as determined from swelling measurements, the ratio of isotropic length to original length falls on a straight line at values above 1 percent cross linkage. Deviations are found below this value because the chains are not perfectly oriented. Above: The isotropic melting temperature of natural rubber networks decreases as the fraction of units cross linked increases. This change is more pronounced for chains that are random prior to linkage.

Fourth International Symposium on the Chemistry of Cement

TO ACCELERATE exchange of information and thus to establish closer coordination on research in cement, the Bureau and the Portland Cement Association jointly sponsored the Fourth International Symposium on the Chemistry of Cement.[1] The Symposium was held from October 3 to 7 at the Bureau in Washington. Approximately 300 scientists from the United States and more than 30 other countries attended the sessions. The last international symposium on cement was held in London in 1952.

Dr. Wallace R. Brode, former Associate Director of the Bureau and former science advisor to the Department of State, and Dr. F. M. Lea, Director of the Building Research Station, United Kingdom, were the guest speakers of the opening general session. In his address on "Some Problems Associated with the Growth of Science," Dr. Brode stated that good coordination and communication are needed on all national and international levels to advance the spread of science and technology.

Reviewing the progress in the field of cement research since the last Symposium, Dr. Lea spoke on "Cement Research, Retrospect and Prospect." He pointed out that perhaps the most notable feature of this Symposium in comparison with the 1952 meeting, is the increased proportion of papers bearing on the hydration of cements. Recent research has led to a fair picture of the chemical and physical nature of set cement, but much remains to be learned about the kinetics of the initial reactions and the mechanism by which the initial framework of setting cement is developed.



After the opening general addresses, technical sessions devoted to specific aspects of cement chemistry were held. The topics were: Chemistry of Clinker, Chemistry of Hydration of Cement Compounds, Chemistry of Hydration of Portland Cement, Properties of Cement Paste and Concrete, Destructive Processes in Concrete, and Special Cements. Within each session two or more principal review papers were presented in condensed form. These were followed by shorter papers dealing with specific investigations, which, in turn, were followed by both prepared and informal discussions.

Cement Clinker

The chemistry of portland cement clinker, in its broader aspects, was fairly well understood even prior to the previous international symposium. Therefore, investigations since then have dealt mainly with such subjects as solid solutions, the effects of minor constituents, and new and improved experimental procedures. Considerable work has been done in the United Kingdom and elsewhere to determine the extent and nature of a solid solution of magnesium oxide and aluminum oxide in tricalcium silicate to form the clinker mineral known as alite. Universal agreement has not been reached on this subject. Development and use of improved techniques for estimating clinker constituents by X-ray diffraction analysis evoked considerable discussion.

Hydration

Although the chemistry of hydration of cement compounds has been a very active field, hydration is still not thoroughly understood. Through the work of S. Brunauer and coworkers at the Portland Cement Association, as well as numerous other investigators, some of the products of hydration have been established. According to Dr. Brunauer, the two chief constituents of cement—tricalcium silicate and β-dicalcium silicate—combine with water at ordinary temperature to produce calcium hydroxide and a hydrated calcium silicate similar to natural tobermorite. However, under hydrothermal conditions, the same anhydrous compounds, or oxide mixtures of equivalent compositions, yield a large number of different calcium silicate hydrates. The relationships of the several species and their conditions of stability were discussed by H. F. W. Taylor (University of Aberdeen, Scotland). Hydrated aluminates, ferrites, and sulfoaluminates have also been studied.

Among numerous techniques now being used for studying hydration are infrared absorption and radioactive tracers. Having conducted experiments with radioactive calcium, T. Thorvaldson (University of Saskatchewan, Canada) pointed out that calcium exchange occurs between hydrated tricalcium silicate and calcium hydroxide solution when these two substances are in equilibrium.

Detailed investigations are being carried out on the hydration of portland cement—a very complex reaction involving numerous steps with different rates. From these studies, it has been established that hydrated portland cement consists of crystalline materials. Here again, many new techniques and methods have been utilized. For differential thermal analysis, equipment for heating four samples simultaneously while automatically recording thermal effects was described by Kenneth Greene (Ideal Cement Co.). By applying this method to cements that have been in contact with water for increasing periods of time, information is obtained on the progressive formation of hydration products—identifiable by their characteristic thermal effects. Development of a successful system of X-ray diffraction analysis of hydrated cement was described by D. L. Kantro and L. E. Copeland (Portland Cement Assoc.). Nuclear magnetic resonance is being applied to a study of the nature of bonding of the water in hydrated calcium silicates and in cements.

False set, a troublesome phenomenon familiar to the cement industry but imperfectly understood, was reported on by W. C. Hansen (Universal Atlas Cement). Although there is general agreement that false set may result from the presence of partially dehydrated gypsum in the cement, the effects of composition, temperature, and aeration are very complex, and the problem cannot yet be considered entirely solved.

Cement Paste

Knowledge of the structure of hardened cement paste has been widely extended through the use of the electron microscope, as related by A. Grudemo (Cement and Concrete Institute of Sweden), W. Czernin (Austrian Cement Research Institute), and L. E. Copeland and Edith Schulz (Portland Cement Assoc.). The silicate formed by the hydration of the calcium silicates appears gelatinous under the ordinary microscope, but is shown by the electron microscope to consist of either acicular particles or exceedingly thin, flexible foils—depending on conditions of hydration. T. C. Powers (Portland Cement Assoc.) pointed out that chemical

composition has little effect on the physical properties of cement paste within the range of normal cements. The hardened paste is a colloidal material having a surface area of the order of 200m²/g, very much higher than that of the unhydrated cement. It is the structure, rather than its composition, which largely determines such mechanical properties of the cement—and hence, of the concrete—as strength, elasticity, volume changes, and creep.

One phase of research on destructive processes in concrete concerns chemical reactions involving aggregates. N. Plum (Danish National Institute of Building Research) particularly stressed the alkali-aggregate reaction which has resulted in much damage in the United States. Investigations were made at the Bureau on the deterioration of hardened cement in aggressive solutions. From a series of mortar-bar tests of various types of cement exposed to different aggressive solutions, supersulfate cements—widely used in Europe where high resistance to disintegration is desired—were found to perform no better, in many cases, than special cements common in this country. P. Nerenst (Danish Gas Concrete Inc.) suggested a mechanism for the effect of frost action in concrete.

Special Cements

V. V. Mikhailov (Academy of Construction & Architecture, U.S.S.R.) stated that an expanding cement which may be self-stressing has been developed. The cement consists of an interground mixture of aluminous and portland cements and gypsum in a small amount of water. When this cement is immersed in water for short periods, expansion occurs. According to Dr. Mikhailov, this expansion can be controlled to give the desired degree of stressing.

Little is known about the influence of the different chemical components of pozzolans. However, G. Malquori (University of Naples, Italy) reported that he had found that the silica and alumina constituents of pozzolans react to form products nearly the same as those formed in the hydration of portland cement. Reactions involving the iron and alkali components of pozzolans have not, as yet, been determined. The most significant finding in high-alumina cements—as reviewed by P. L'Hopitallier and presented by R. Rabot (LaFarge Cement Co., France)—is that the chief hydration product is monocalcium aluminate hydrate, rather than di- or tricalcium as earlier believed.

The Symposium was followed by three days (October 10 to 12) of seminars and discussions at the Research and Development Laboratories of the Portland Cement Association in Skokie, Illinois.

[1] *The proceedings of the Symposium will be published in late 1961 by the National Bureau of Standards.*

Chemistry Division Reorganization Announced

THE BUREAU's chemistry activities have recently been reorganized. Two new divisions, Analytical and Inorganic Chemistry, and Physical Chemistry, have been formed from the former Chemistry Division, together with some sectional activities from other divisions. An important purpose of the reorganization is to focus more directly on the Bureau's basic responsibilities for precision measurement techniques and for precise data on the properties of materials. Details of the makeup of the two divisions are shown at left.

*Analytical and Inorganic Chemistry**

Chief of Division	Dr. I. C. Schoonover (Acting)*
Assistant Chief	Dr. R. G. Bates*
Consultant*	Dr. C. P. Saylor*
Pure Substances	Dr. F. L. Howard*
Spectrochemistry	B. F. Scribner
Solution Chemistry*	Dr. R. G. Bates
Analytical Chemistry	J. L. Hague (Acting)
Inorganic Chemistry	Dr. R. Gilchrist

*Physical Chemistry**

Chief of Division	Dr. M. B. Wallenstein*
Thermochemistry	E. J. Prosen
Surface Chemistry	(vacant)
Organic Chemistry	Dr. H. S. Isbell
Molecular Spectroscopy	Dr. D. E. Mann
Molecular Kinetics	Dr. R. E. Ferguson*
Mass Spectrometry	Dr. V. H. Dibeler*
Molecular Structure and Radiation Chemistry*	F. Buckley

Note: * indicates new organization title or name of new chief or consultant.

Dr. Edward Wichers, who is now an Associate Director of the Bureau, had been serving as Acting Chief of the Chemistry Division prior to the reorganization.

The Analytical and Inorganic Chemistry Division will be responsible for devising and improving methods for purification, analysis, and characterization of materials, including standard reference substances; for fundamental investigations of reactions suitable for preparation of pure substances; for investigations of the phenomena on which the measurement of the composition and behavior of chemical systems is based; and for related researches.

The responsibilities of the Physical Chemistry Division will include determination and publication of standard values of thermodynamic parameters of gaseous, liquid, and solid materials, of geometry and energy parameters of molecules, such as shapes of molecules, free radicals, and ions in normal and excited electronic states; determination and interpretation of kinetic behavior of chemical systems under thermal conditions at low energy and under the influence of high and low energy radiation. This Division will con-

uct a broad basic research program in experimental and theoretical studies of the elementary processes of chemical reactions, and will provide consultation and advisory services on technological problems of importance to other agencies and the public.

Biographical Sketches, Analytical and Inorganic Chemistry Division

DR. IRL C. SCHOONOVER, Acting Division Chief—(continues as an Associate Director of NBS); born in Belington, W. Va., 1906; BA in chemistry, George Washington University, 1929; MA in chemistry, Princeton University, 1932; Ph. D in chemistry, Princeton University 1933; joined NBS staff in 1928 and, with interruptions in 1931–1935 and 1944–1945, has been a member of the Bureau ever since.

DR. ROGER G. BATES, Assistant Division Chief—formerly Acting Assistant Chief of Division and Chief, Physical Chemistry Section; born in Cummington, Mass., in 1912; BS in chemistry, University of Massachusetts, 1934; MA in physical chemistry, Duke University, 1936; Ph. D in physical chemistry, Duke University, 1937; joined NBS staff in 1939.

DR. CHARLES P. SAYLOR, Consultant—formerly Chief of the Pure Substances Section; born in Camden, N.J., in 1901; Bachelor of Chemistry, Cornell University, 1923; Ph. D, chemistry, Cornell University, 1928; joined the Bureau in 1931.

DR. FRANK L. HOWARD, Chief of Pure Substances Section—formerly Chief of the Molecular Kinetics Section of the Heat Division; born in Pueblo, Colo., 1913; BS, chemistry, University of Maryland, 1934; Ph. D, organic chemistry, University of Maryland, 1938; joined NBS in 1937.

Biographical Sketches, Physical Chemistry Division

DR. MERRILL B. WALLENSTEIN, Division Chief—formerly a consultant in physical chemistry to the Bureau's Associate Director for Chemistry; born in Idaho Falls, Idaho, in 1920; BS in physical chemistry, 1948, University of Utah; Ph. D in physical chemistry, 1951, University of Utah; member of Bureau staff from 1952 to 1955; rejoined NBS in 1959.

DR. ROBERT E. FERGUSON, Chief of Molecular Kinetics Section—formerly member of Molecular Kinetics Section of Heat Division; born in Seelyville, Indiana in 1923; BA, mathematics, State University of Iowa, 1949; Ph. D, physical chemistry, 1952, State University of Iowa; joined NBS in 1952.

DR. VERNON H. DIBELER, Chief of the Mass Spectrometry Section—formerly a member of the Mass Spectrometry Section, Atomic Physics Division; born in Elizabeth, N.J., 1918; BS, chemistry, Duke University, 1939; MS, chemistry, 1940, Duke University; Ph. D, chemical physics, 1950, Columbia University; joined NBS in 1942.

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